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DIGITAL CHART DATABASE CONVERSION INTO A SYSTEM ELECTRONIC NAVIGATIONAL CHART

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2.1 Introduction

DX90 is a new international exchange standard specifically developed by the International Hydrographic Organization (IHO) for the transfer of digital hydrographic data [2]. The National Oceanographic and Atmospheric Administration/National Ocean Service (NOAA/NOS) has adopted DX90 and is using it to produce vector-based digital nautical charts.

This report provides a brief description of this standard and an overview of the process that will likely be required to transform DX90 chart data into a form suitable for Electronic Chart Display and Information System (ECDIS) applications.

2.2 Background

DX90 uses the implementation methodology from the International Standard ISO 8211. ISO 8211 is a specification for a data description file for information interchange and is intended to standardize information processing. ISO 8211 was primarily developed to facilitate data transfer between dissimilar computer systems as well as being media-independent.

The goal in developing DX90 as an interchange format is to facilitate the transfer of Electronic Navigational Chart (ENC) data from any Hydrographic Office (HO) to a vendor system without loss of structure or content. DX90 specifies a method for describing a robust interchange structure which can accept most user data structures. This method enables the HOs to preserve structure and data and convey it to the vendor. The vendor can then reproduce the structure and data into his or her system.

This goal is accomplished by embedding generic record format descriptions into the data (a process known as self-documenting). This structure ensures compatibility with many systems and enhances the performance of data by enabling all the data to be used. The one drawback of the ISO 8211 standard is its inefficiency. It does not use indexes or lookup tables. For ECDIS applications, an ISO 8211 data file will need to be transformed before it can be readily used for processing and displaying electronic charts.

2.3 Geographic Information System (GIS) Database Transformation

The transformation of any standard data file format to another standard data file format is not a new concept or process for Geographic Information Systems (GIS). Since ECDIS can be regarded as a type of "real-time" GIS, the challenges associated with any GIS database will likely apply to DX90 as well. GIS users must transform one database structure into another until a database structure is achieved that is compatible with their particular GIS requirements. The same database transformation process will need to be performed for ECDIS applications.

2.4 Hydrographic Office (HO) to Vendor Transfer of ENC

Figure 1 is a simple diagram that shows the conceptual process by which a national Hydrographic Office (e.g., NOAA/NOS) transforms its "in-house" Electronic Navigational Chart (ENC). The vendor then takes this ENC data and transforms it into a System Electronic Navigational Chart (SENC) suitable for ECDIS applications such as displaying a nautical chart. The following two sections describe this process in more detail.

Transformation Process Performed by Hydrographic Offices

In order to produce digital chart data suitable for ECDIS, Government HOs must convert existing chart data (usually in analog form, but may be digital) into ISO 8211 Data Description Files (DX90). As shown in Figure 2, this can occur in one of two ways. The first process involves two steps. The first step requires a conversion from an "in-house" Electronic Navigational Chart Database (ENCDB) into an intermediate format that conforms with the specifications from the IHO Object Catalog [3]. The software required for this conversion process will likely be developed by each Government HO.

The second step is to convert these intermediate files into ISO 8211 Data Description Files. In Electronic Chart or ECDIS terminology, this dataset is referred to as the Electronic Navigational Chart (ENC). The advantage of this two-step process is that there is commercially available software which performs this process of converting data from a relatively simple file format into fully conforming ISO 8211 files. It is called "ISO 8211 Implementation Software" or Alfred Brooks Data Description File System (DDFS) Software

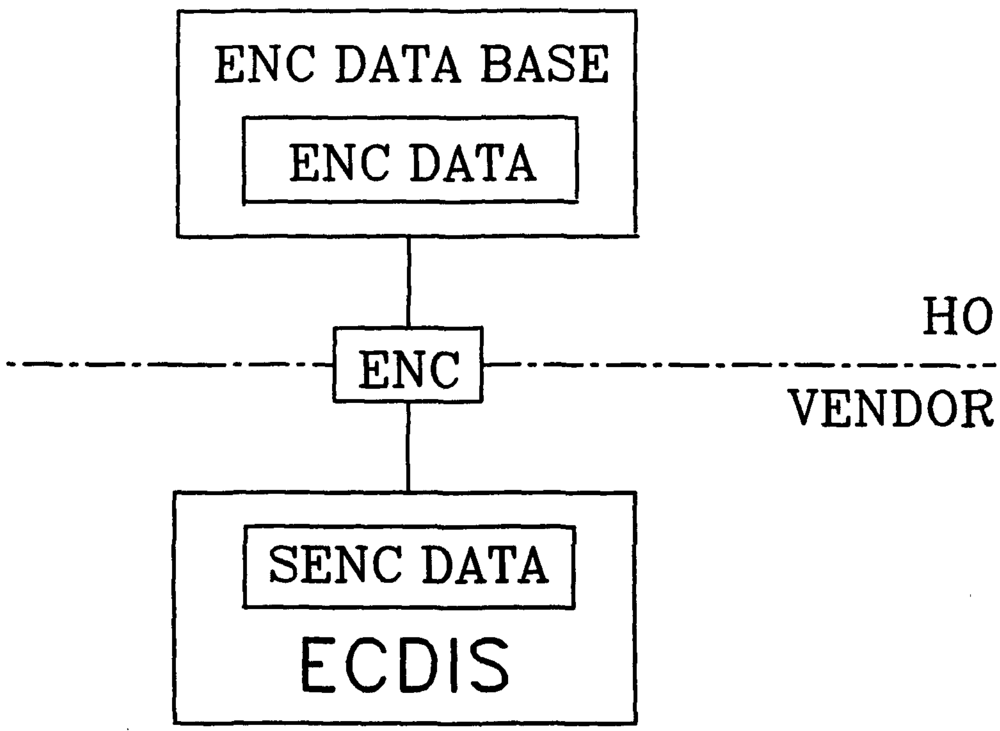

Figure 1. HO to Vendor Transfer of ENC

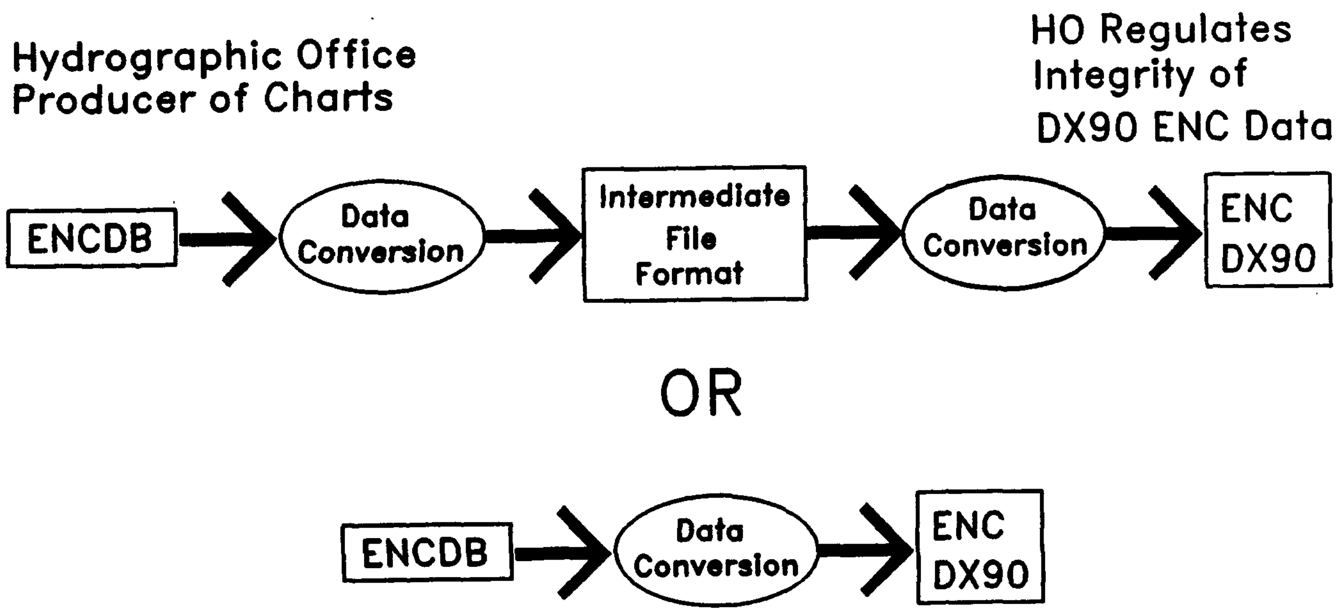

Figure 2. ENCDB Transformation by Hydrographic Office

[4]. Some Hydrographic Offices may also choose to develop their own software to perform this second step conversion process.

The second process involves one step. It may be the choice of some HOs to develop their own software to perform this entire process in one step. NOAA/NOS has chosen this second approach. This software is being developed as part of the Automated Navigational Chart System (ANCS II). This approach will require more work up front to develop the software, but less work in the long run with only one conversion process to verify, not two.

<u>Transformation Process Performed by Vendor</u>

After obtaining the Government HO-provided Electronic Navigational Chart (ENC) in DX90 format, the vendor must transform this ENC data into a form that is suitable for ECDIS applications. As shown in Figure 3, this will likely be a two-step process. The same commercially available software used by the HO to convert the intermediate file format into an ENC can be used for the first step of this process. Also available with the DDFS Software is an application that validates the data and data description in the two files. By producing an error message when a discrepancy is detected, this helps in assuring valid data will be used in the second step of the process. The second step must be developed by the vendor. It involves converting the intermediate format files into an electronic chart display that is suitable for ECDIS applications.

Provisional Performance Standards for ECDIS have been developed [5], [6], [7], [8] which will help the vendor in designing an ECDIS. These standards are still provisional, yet give some guidance as to the type of display, the information required to be displayed, reliability requirement, operating controls and specific symbols and colors that an ECDIS must have. Basically the Standards require an ECDIS to display accurate and up-to-date chart information necessary for safe navigation.

2.5 IHO Transfer Standard for Digital Hydrographic Data (SP-57) [9]

The International Hydrographic Organization (IHO) has prepared a document that is an essential information source for any potential vendors to the ECDIS program. The document is divided into three parts describing the IHO Object

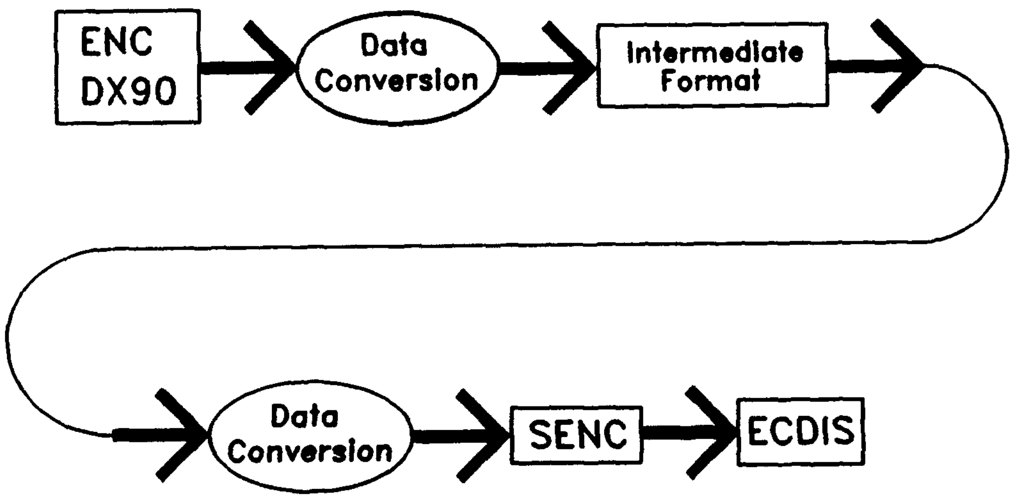

Figure 3. ENC Transformation by Vendor

Catalog, the DX90 transfer standard, and the required digitizing conventions associated with the transfer of analog data from maps to a digital database. The document can be obtained through National Hydrographic Offices.

Part A contains a description of the feature coding schema to be used and introduces the concepts of hydrographic models, object classes and attributes, and symbolization codes. It is a complete description of the required objects for an ECDIS database.

Part B contains an introduction to the ISO 8211 transfer standard, the relationship of the DX90 standard to ISO 8211, data structure of a DX90 exchange set, specifications for the data fields, and a description of the Alfred Brooks Data Description File System (DDFS) software.

Part C contains the digitizing (transfer) conventions in the generation of a DX90 data set from analog chart data.

The hard copy contents of the Standards document are a subset of the entire document which is provided on MS-DOS compatible 3.5 inch floppy disks as ASCII files accompanying the document.

Also provided as part of the standard is an example exchange set in digital form on 3.5 inch floppy disks. This set contains the Data Set Description, Catalog, and Feature files describing data illustrated within the document.

It was this data set that ERIM used in their initial investigation into the DX90 standard and is illustrated in Figures 4 through 7 in Part 3 of this document.

3.0 ERIM's Approach to Production of System Electronic Navigational Chart (SENC)

3.1 DX90 to Electronic Navigational Chart (ENC)

The data format DX90 for exchange of hydrographic data conforms to the more general ISO 8211 format for exchange of digital data. DX90 data is a stream of ASCII bytes without carriage return/line-feed control characters; these data appear as a single record when viewed in an ASCII editor. The DX90 standard requires that the boundaries and scale of each electronic chart be defined by the DX90 file name. In theory a DX90 file contains all information which appears on the corresponding paper chart of the same region.

In order to learn about the DX90 format and display the data, the strategy we adopted was to use the Alfred Brooks Data Description File System (DDFS) utilities to create ASCII format .APP files for input and to create a vector format database for display purposes. A brief description of this software follows.

The DDFS utilities are designed to process data conforming to ISO 8211 and create equivalent information in accessible formats. The three utilities provided are:

DDFIMP (DDF Import)

- reads DX90 files, default extension .DDF
- writes data description files, default extension .DDI, moderately accessible format
- writes data files, default extension .DAI, moderately accessible format

DDFFLD (DDF Field Decomposition)

- reads .DDI, .DAI files
- writes application data files in their most accessible form, default extension .APP

DDFEXP (DDF Export)

- reads .DDE, .DAE files, same format as .DDI, .DAI
- writes .DDF files

DX90 Internal Format

Data and their internal format description are both contained within DX90 data files of extension .DDF. At the simplest level, the DX90 data falls into two categories, which can be referred to as "features" and "segments." Feature and segment data are located in .DAI after application of DDFIMP, while the records describing the internal format of both feature and segment data are found in .DDI.

Feature Data - Features are cartographic abstractions of real world features as represented on paper charts and within the DX90 database. A particular feature references either segment data or other feature data (but not both). A feature may be referenced by one or more other features. Feature data includes:

- unique name - 10 characters
- type - line, point, area, cartographic object
- composition - simple, compound, complex
- label - feature type such as AIRPORT, ANCHOR, etc., from DX90 definition catalog
- attributes - optional, indefinite in number, such as common name, depth, period, frequency
- "targets" - the unique names (10 chars) of an indefinite number of segments (simple data) or other features (compound or complex data)

Segment Data - Segments contain the actual vector data necessary to construct a map. In addition to latitude and longitude, certain segments may have depth soundings and "segment attributes." Segments are referenced by features of composition SIM (simple) and do not reference features or other segments. Segment data includes:

- vectors - latitudes, longitudes, optional soundings
- attributes - optional, indefinite in number

Program Requirements

Significant preprocessing of the DX90 data is necessary to satisfy some of the ECDIS standard requirements for scale change and enabling/disabling of selected features. While DX90 data is in a "vector-like" format, the cross- and multi-referencing of various data within a file make the format unsuitable for acceptably fast display processing.

The ability to enable/disable features globally within the display portion of the program requires that each individual feature within the vector database carry a tag indicating its DX90 object label. Further, the ability to enable or disable compound and complex features requires that each feature within the vector database carry a tag indicating either that it is a simple feature or what its parent feature is.

While the standard does not specify a hierarchical limit in the level of composite object construction, the objects defined in the DX90 object catalog have at most one level of parent/child relationships. In other words, no examples of compound or complex features which referenced other compound or complex features were encountered, so the developed program was coded for one level of referencing at most.

3.2 ENC to System Electronic Navigational Chart (SENC) Conversion

Program MAKPN1

MAKPN1 Overview - This program performs the second of two phases of preprocessing of DX90 data, the first phase being the processing of DX90 data by DDFS utilities DDFIMP and DDFFLD. MAKPN1 creates the vector database used by the display program by reading reformatted DX90 data from the ASCII files of extension .APP and producing vector and attribute files with extensions .EDB and .FTR, respectively.

In creating the vector database, MAKPN1 performs the following functions:

* Remove the multi-referencing of particular segments by different features by duplication of the multiply referenced data.

* Create the compound and complex features by tagging particular simple features with the compound or complex feature which referenced them; simple features not referenced by a compound or complex feature are also tagged.

* Count and organize the attributes associated with particular features and associate them with the appropriate vectors.

MAKPN1 Algorithm

1. Separate the .APP data into features and segments in separate files.

2. Search the feature file for compound and complex features. Compile a list of compound and complex objects and the unique names of the particular simple features they reference.

3. Search the feature file for simple features. Compare the unique feature name with the names referenced by compound or complex features and record "parent" object if any or tag as "orphan."

    a. Compile a list of attributes associated with the simple feature.

    b. Compile a list of the unique segment names referenced by the simple feature.

    c. Combine the two lists such that each segment name is associated with all attributes.

4. Read the segment file for unique segment name and the latitude, longitude vectors associated with that segment name. Search the previous list for all reference to that segment name.

5. Create the vector database by creating an attributed vector for each instance of the segment name in the compiled list.

Comments

1. A particular segment may be referenced 0 or more times. If it is not referenced by a feature it is not written to the vector database.

2. A particular segment may be referenced by different features having different attributes.

3. Each vector in the vector database consists of a single record containing 10 integer fields and a character string, followed by a variable number of records containing latitude, longitude pairs.

4. The integer fields and character string (implicitly) contain the required attributes associated with the feature.

5. Each attribute record, together with the latitude and longitude vectors which follow, amounts to a complete feature containing all information originally pertaining to that feature. The process of creating the complete vector feature is entirely a matter of associating various data which is not physically contiguous within the original DX90 data.

6. As new objects are located during the first pass through the feature file, they are recorded in a table. Within the vector database, tagging is accomplished by recording the index of the feature, and the index of the parent feature, if any.

SENC Database Format

A complete database consists of two files, one of extension .EDB and the other of extension .FTR. The .EDB file contains vector and ancillary data for display. The .FTR file contains a list of DX90 features contained in the database, plus a one to three word explanation of the feature.

The vector database format consists of a series of vector units. Each unit consists of:

* One line containing 10 integer number fields plus one (1) ASCII character string field.

* One or more lines containing 2 floating point number fields of latitude and longitude pairs.

The integer fields are referred to as (i), that is, (1) refers to the first integer field.

Example

....code (i)....

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
4	4	0	0	0	0	0	15	-1	4	IN12.1-B

.028500	.033280
.019990	.035960
.031610	.043640
.040490	.037680

All vectors contain the following definitions:

(1) Contains the number of latitude, longitude pairs which follow. There will always be at least one latitude, longitude pair.

The value of (2) specifies additional data about the vector:

(2) = 0 indicates that the lat/long coordinates should be connected by a line.

(2) = 1 indicates that the feature is a SOUNDG (sounding). The associated depth is encoded as ASCII in the character string. Only one lat/long pair follows.

(2) = 2 indicates that the feature is a $CSYMB (cartographic symbol). In this case:

(3) contains $ROTAT, the clockwise angle through which the symbol should be rotated from N;

(2) = 3 indicates that the feature is a $TEXTS (ASCII text), which is encoded in the string.

In this case:

(3) = 1 or 2 = upright text or italics text

(4) = "body size in italics"

(5) = horizontal justification

= 0 undefined
= 1 center
= 2 left
= 3 right

(6) = spacing

= 0 undefined
= 1 "expand/condense to fit"
= 2 standard

(7) = color

= 0 undefined
= 1 white
= 2 black
= 3 red
= 4 green
= 5 blue
= 6 yellow
= 7 grey
= 8 brown
= 9 amber
= 10 violet
= 11 orange
= 12 white/red
= 13 white/green

(2) = 4 indicates that the feature is $LINES (special line type). In this case (10) contains an index to a table of INT1 symbol names, which are also coded in the character string (see below).

(8) Contains an index to the list of features in the .FTR file. Indices start at 0. In this way each vector is associated with its DX90 feature name.

(9) Contains an index to the list of features in the .FTR file if the feature is accessed by a CMP (compound) or CPX (complex) feature; or -1, otherwise (SIMP or simple feature).

(10) Contains an index to the following table of INT1 symbol names, which are also coded in the ASCII string:

(10) = 1 IP1-C
= 2 IN21-A
= 3 IN20-A
= 4 IM10 (ARROW)
= 5 IK1
= 6 IY2
= 7 IN12.1-B
= 8 IP40-A

SENC Display

ERIM developed a system to demonstrate the processing steps that will be involved in the transformation of the NOAA/NOS supplied DX90 ENC data into System Electronic Navigational Charts (SENC). ERIM has also developed a display package on an Intel 80386 based MS-DOS system with standard VGA graphics and a Microsoft compatible mouse. The purpose of this display package is to demonstrate and assess the real-time display of the developed SENC. While this is not a fully functional ECDIS, several of the features for ECDIS specified in the RTCM SC 109 Recommended Standards for ECDIS [10], and the IMO Provisional Performance Standards for ECDIS [5], [6], [7], [8] have been incorporated.

The display package, operates on processed DX90 data files that have been placed in a hybrid of ERIM's vector-based polygon files to facilitate the graphic display of the data.

The current version of the SENC Display shows the DX90 file in a rectangular map projection whose scale is determined by the geographic extent of the database. While no standard map projections are currently supported, their addition would involve relatively minor changes to the program.

Symbols in the DX90 database, such as "NO FISHING", "NO ANCHORING", and "OBSTRUCTION" are treated as user-specified characters during the display process. This was accomplished by using a stroked-font editor to create a library of symbols found in the sample database provided by the Coast Guard. Once the library, or font file was created, drawing symbols is simply a special case of writing text on the screen. Stroked fonts, which are essentially vector representations of letters, have the added virture of being easy to draw at various sizes and angles using the standard graphics library in TURBO C. Note that the font file created contains only those nautical symbols that were encountered in the sample database provided to ERIM.

Description

The SENC Display was designed to run on any IBM PC, XT, AT or compatible computer system with a disk drive (hard drive recommended). The system should also have a minimum memory of 256Kb, a VGA graphics card and monitor capable of supporting 640 columns, 480 rows, and 16 colors, and run under DOS 2.0 or higher. The software was written in TURBO C 2.0. All of the graphics within the program were generated using Borland's Borland Graphic Interface (BGI) graphics library (included with TURBO C). The user interface (menus, buttons, and icons) utilized Island System's Graphics Menu and Data Entry packages.

Conceptually, the SENC Display has three major components: (1) the user interface, (2) the graphics interface, and (3) the I/O interface.

The user interface was built using Island System's Graphics Menu & Data Entry toolkits. The SENC Display interface utilizes a set of icon buttons and pop-up windows which may be activated or controlled via a Microsoft compatible mouse as well as via keyboard commands.

The I/O interface handles all interaction between the main program and the data files used in the SENC Display. These files include the converted DX-90 vector file, a feature and status file, and an internal help file.

The graphics interface handles the actual display and plotting of the vector data files using Borland's BGI graphics library.

System Features

* Browse-through, on-line help system

* Plot a converted DX-90 database

* Zoom in on a selected portion of a DX-90 file

* Interactively select features to view in the database.

* Easily locate a displayed feature within the converted DX-90 database

* View the converted DX-90 database in both graphics and text modes

* Show geographic coordinates of cursor location

Representative SENC Display screens are shown in Figures 4 through 7.

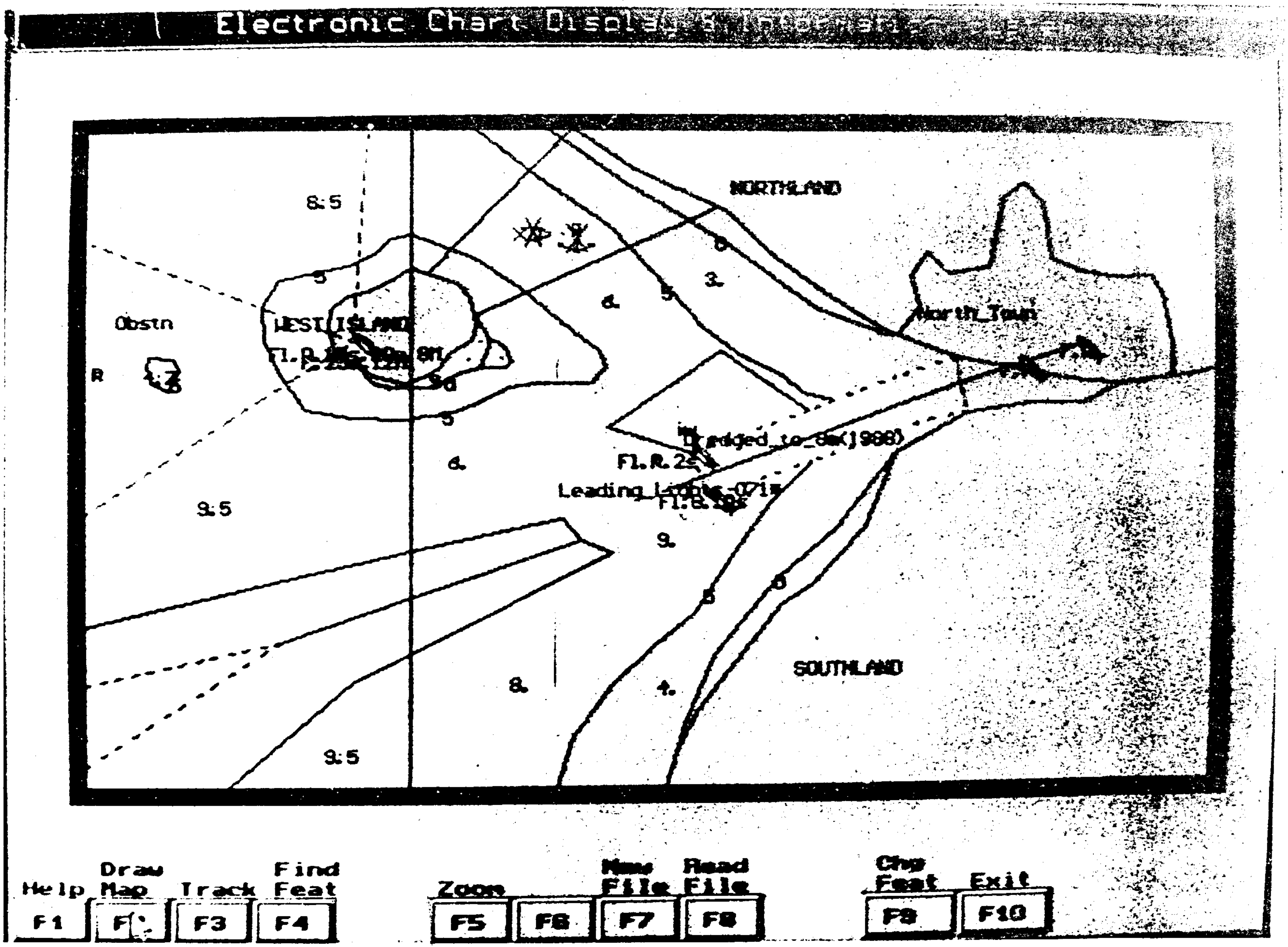

Figure 4. SENC Display-Draw Map

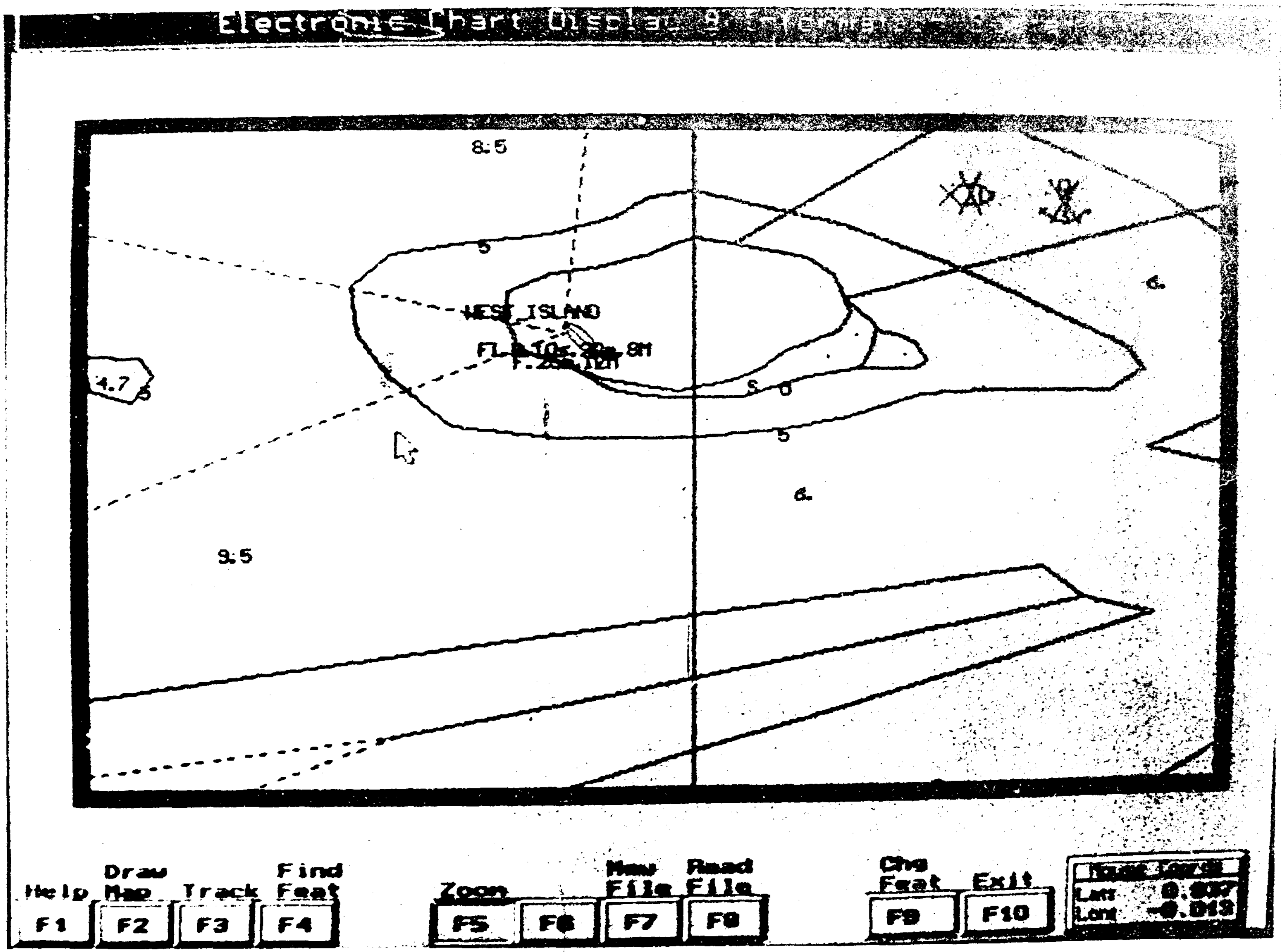

Figure 5. SENC Display-Zoom

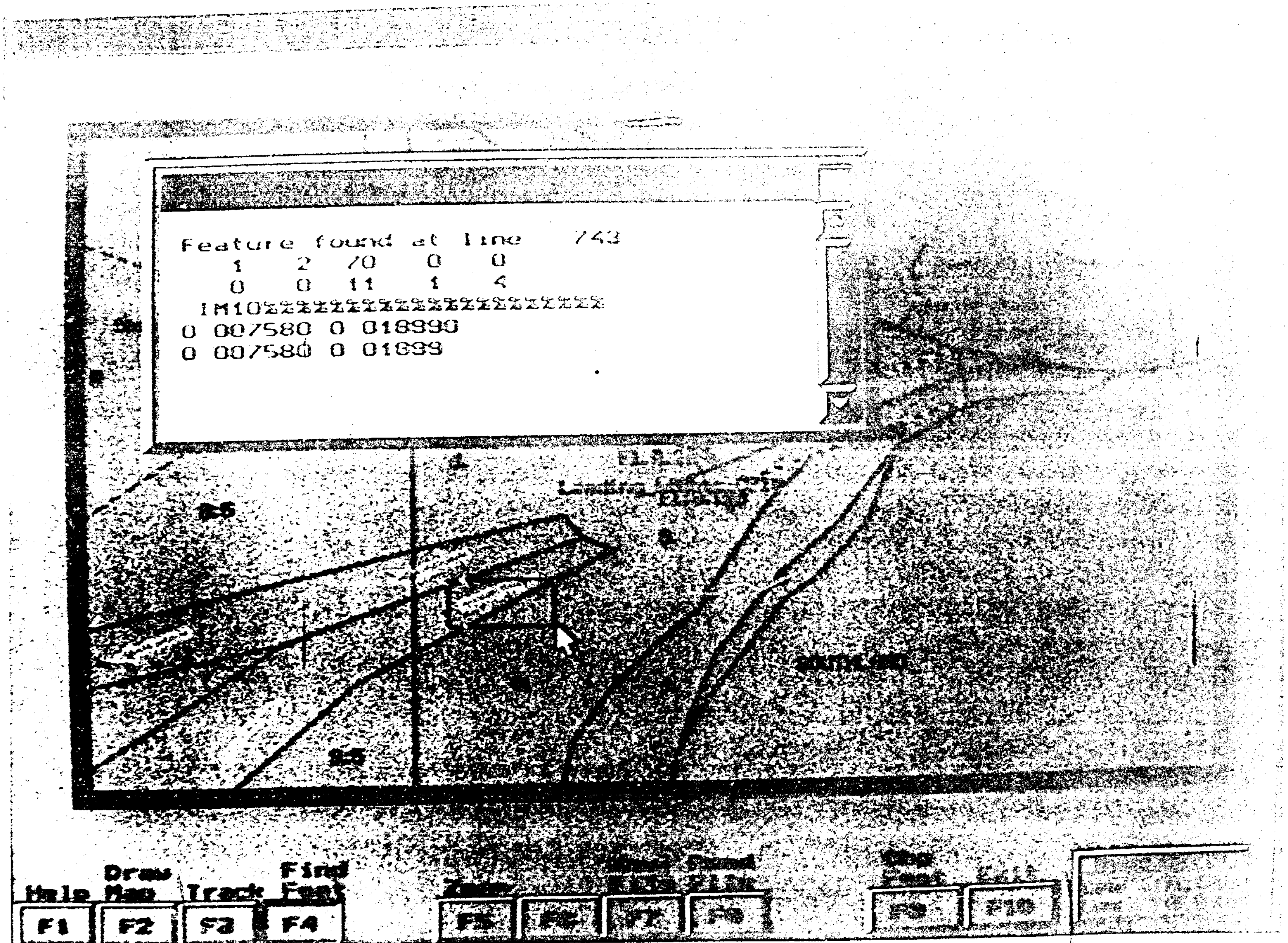

Figure 6. SENC Display-Find Feature

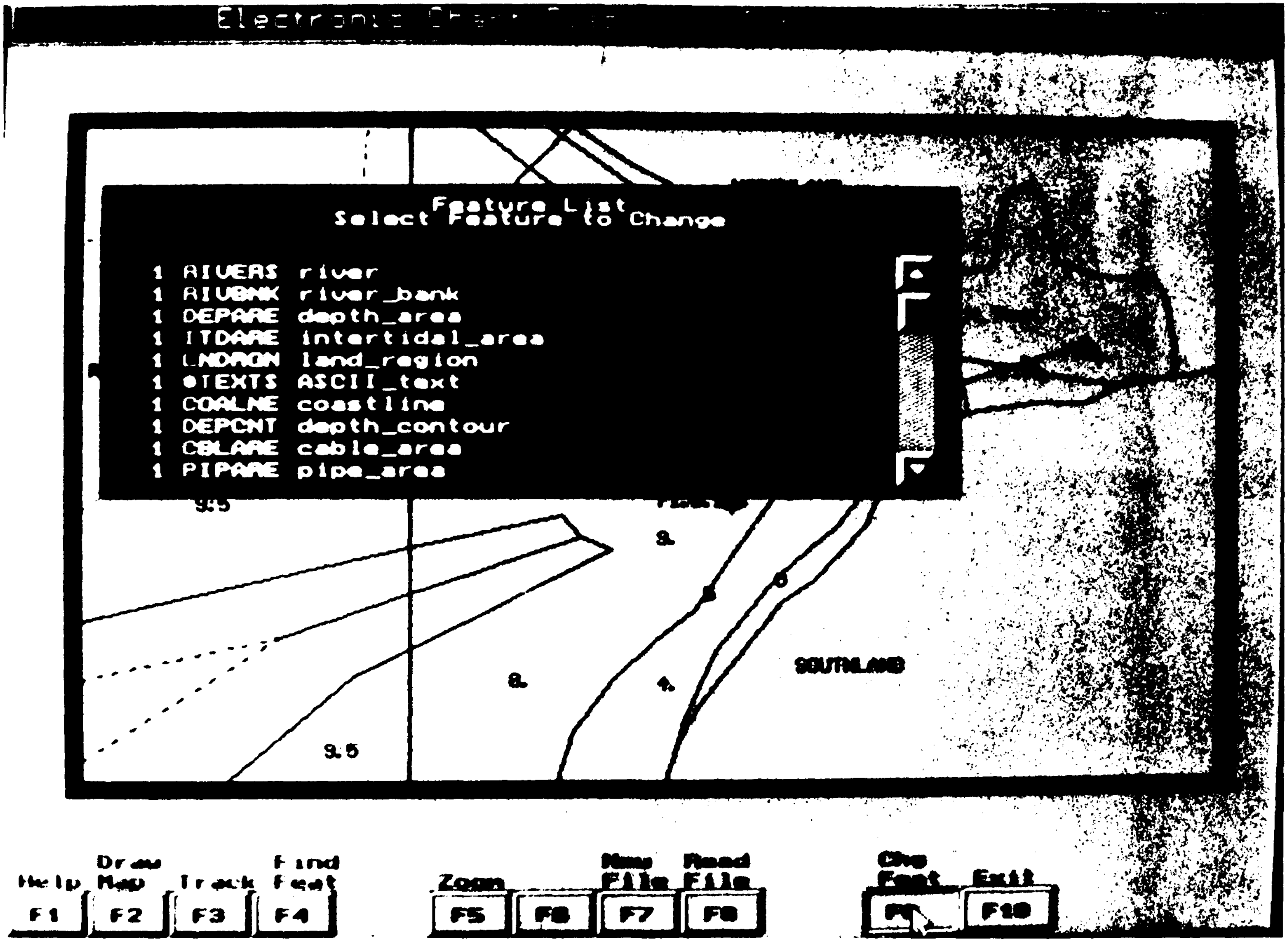

Figure 7. SENC Display-Change Feature

4.0 Lessons Learned

4.1 Status of DX90 Implementation

A great deal of time has been spent by various committees within the IHO to define the transfer standard, however actual production of DX90 format data within the Hydrographic Offices is just now beginning.

The initial database that was provided was a pseudo geographic cell that was only developed to work out the transcription of analog (chart) data to a digital form and then to DX90 format. Using the DDFS utilities, it was not difficult to review the data structure. It appeared that the facility that generated the data did not have the equivalent of these utilities, however, since one of the delivered data sets would not pass the DDFS validity checking. Once these data sets were analyzed and corrected, using visual examination of the ASCII data, the actual ENC to SENC transformation began.

As soon as the converted ENC data were displayed, it was much easier to review the results of the digitization. The main problems included:

1. Undefined features

2. Improperly coded features

3. Features with improper attribute codes (e.g., wrong rotation angles, etc.)

By using the display program software, it was easy to identify things wrong with the database by examining the graphic presentation. Using an iterative process, corrections were made to the provided database through editing of the textual information.

All the problems could not be solved in this manner. Some involved missing symbols and constructs that were not available within the display software developed.

In summary, there are still problems, if the delivered databases are indicative of the current implementation level, in (1) the interpretation of the digitized data, (2) the integration of the colors and symbology with the interpreted data, and (3) the consistency of colors and symbols.

Until sufficient experience within the Hydrographic Offices in the production of the DX90 data is achieved, the quality control aspects of the process will be extremely burdensome but vital.

4.2 Capability of DX90 Transfer Standard to Support ECDIS

The question of the capability of the DX90 transfer standard to support ECDIS can be answered on two levels: (1) is it robust enough in its structure to provide all of the information required from the navigational charts to replace paper charts and (2) is the structure of the DX90 data format appropriate for ECDIS?

The DX90 standard should be viewed as equivalent to an Electronic Navigational Chart for data exchange purposes. The standard was developed to address data transmission efficiency and not for any particular end use (such as ECDIS). Therefore, it will become the responsibility of every potential vendor of ECDIS equipment to map the ENC data to a proposed hardware platform and optimize the internal data structure for the display and manipulation functions. This is equivalent to the effort on this contract in the development of the MAKPN1 and ECD Display software components.

Secondly, the structure of the DX90 standard is capable of transmitting all of the information required for the ECDIS. The difficulty in this regard will be the effort required to develop translators for a number of different platforms in order to allow reliable and verifiable transmission of the digital data. For example, no translator currently exists for a Sun platform. Verifying the reliability of the translation process will become a major responsibility for some agency in the ECDIS chain. An additional difficulty in this regard is the verification of the translation process accuracy. It is conceivable to envision a translator that would introduce a systematic error in going from an internal data format to the DX90 format which, if used in the reverse direction, would faithfully reconstruct the internal data format. Assigning responsibility for this translation process verification is a problem that must be addressed.

4.3 Capability of DX90 Transfer Standard to Support GIS Activities

DX90 is capable of supporting GIS activities if suitable structuring of the transferred data is achieved. In order to understand some of the questions that still need to be asked about the use of DX90 data for GIS activities, a brief background in Geographic Information Systems follows.

Geographic information systems are designed to handle spatial data. Conventional database management systems (DBMS) are applicable to spatial data, but they have severe limitations. The first problem is the large volume of data normally associated with geographic databases. In addition, spatial databases require two- and three-dimensional relationships, which are not normally encountered in business-oriented applications. The requirement to handle large data files incorporating a wide variety of spatial relationships make it impossible to store all of these relationships explicitly, even if all the required relationships could be anticipated.

The critical difference between a GIS and conventional information management systems is based primarily on two facts: (1) the data has associated geometric aspects that play an important role in the analysis process, and (2) a geographic information system routinely operates in an environment where it is difficult, if not impossible, to precisely define the required task. The means the system cannot be designed for a well-defined purpose but must be robust enough to support a variety of uses.

To elaborate on the first point: in any GIS thematic data is irretrievably linked with geometric and positional information. In a nautical GIS the thematic data might include soundings, shorelines, navigational aids, other vehicle positions, etc. There are basically two ways to link thematic and geometric data: (1) the thematic data is directly linked to positional information or (2) the objects (features) are identified and the thematic features and geometric data relate to these objects. The first approach is generally implemented in raster-based systems in which each element has a fixed position in a regular grid and the thematic information is stored on a per element basis. The second approach is normally implemented in a vector-based system. The geometry of the features are normally defined by points (nodes) and lines (arcs), which can define point, linear, and areal objects.

Until recently these two approaches were generally implemented in different geographic information systems. In many current systems, these different data structures are integrated so that the advantages of both data structures can be utilized. The raster data structure is very computationally efficient for analyzing multisource data layers. On the other hand, the vector data structure is very powerful due to its topological nature, which aids in the analysis of the spatial relationships in the data. A second advantage of this data structure is the ability to present the data in a wide variety of scales while still retaining the underlying accuracy of the origina_ input data.

What does all this mean in the evaluation of the applicability of DX90 data to a nautical GIS? First, the DX90 data is already stored as positionally related information. The positional accuracy of this data is totally dependent on the charts available to the national Hydrographic Offices, which presumably are the best available. Second, assuming the DX90 standard is accepted as an international transfer standard, there will be consistent, reliable global data generated related to nautical features. This data availability is a critical point since it has been widely estimated that 80 percent of the actual cost of a geographic information system is the database generation.

What is it going to take to utilize DX90 data in an operational GIS? First, an appropriate hierarchical data structure for the GIS must be developed based on at least a representative list of anticipated applications. The prime considerations in the choice of this data structure are (1) the system overhead associated with various retrieval techniques which might be employed, and (2) the data sources to be utilized in the database. Once the data structure has been determined, the DX90 data must be transformed from its transmitted form into the feature identifiers, thematic data, and positional data components commensurate with this structure. A decision must be made at this juncture whether it is possible to define a internal data structure that is applicable to both the real-time requirements of an ECDIS and the complex analysis requirements of a GIS.

What then are the advantages and disadvantages to using DX90 for GIS applications? As noted above, the main advantages to its use is the adequacy of the information content for many applications and the hoped-for availability of consistent and reliable global data. The major disadvantage will be the effort associated with design of the appropriate database structure for representative GIS applications, and the development of software components to translate the DX90 format data to this structure. This disadvantage should, however, be viewed as an unique opportunity to define an area that has been largely ignored up to this point to apply GIS technology to the solution and management of maritime problems.

5.0 Follow-on Recommendations for RDT&E Activities

5.1 Generic DX90 SENC Display

One thing that would greatly enhance the Coast Guard's ability to evaluate the DX90 ENC data would be an expansion of the SENC Display software developed under this project to a display for the entire ECDIS Object Catalog. Due to not only budgetary restrictions but also data availability, the implementation of object and symbol display was limited to those features found in the databases furnished to ERIM. It would be a rather routine matter using the developed translation and display software to expand this capability. This is probably the most cost-effective application of any future funding.

5.2 Interactive Editing of Translated ENC Databases

Based on already implemented approaches to determining construction of the displayed objects from the initially translated DX90 data, it would be possible to add capability to the display software to identify and trace back those objects that appeared to be in error. These errors could be coding or attributing errors. This capability would allow "cleaning-up" of databases on a short-term basis to permit use of the data to answer the real questions rather than having to wait for corrections to be supplied by the issuing HO.

5.3 Prototype GIS Database Structure

Should the Coast Guard desire to engage in a more thorough investigation of the required processes in the use of DX90 and other data in a real GIS workstation environment, a prototype GIS database structure could be developed and implemented. This activity would be the most extensive and, therefore, the most costly of the three potential activities but the "heads-up" view of this activity in determining integration process requirements may be well worth the investment.

APPENDIX A. SOFTWARE OPERATING INSTRUCTIONS

General Instructions

1. Create a working directory and copy the DX90 data files (XXXXXXXX.DDF) into it.

2. Copy the two DDFS Utilities (DDFIMP.EXE and DDFFLD.EXE) either into the same directory or into a separate directory. If the executables are in a separate directory, define a PATH to that directory.

3. Copy the MAKPN1.EXE into either the working directory or the executable directory, if different.

4. Create, in the same directory as MAKPN1 is stored, a data file named MLIST.INP using any text editor available. This file should contain feature names and a brief description for each, taken from the ECDIS Object Catalog [3] for features expected in the input data sets. The format for this file is as follows:

   1X,6A1,1X,40A1

   where first ASCII field (6A) contains the ECDIS object name, such as: RIVERS and the second ASCII field (40A) contains any descriptor the user wants associated with that object.

   This file is used by MAKPN1 to create feature lists for the SENC display program.

5. Change Directory (CD\) to working directory.

DDFIMP - DDF Import

The following sequence will generate the data description (*.DDI) and data files (*.DAI) for the current data set(s).

<CR>=Carriage Return

TYPE:	DDFIMP<CR>	.. starts program
TYPE:	<CR>	.. skip to 2nd menu

```
TYPE:     XXXXX              .. process this file
TYPE:     YYYYY              .. continue
            .
            .
TYPE:     <CR>               .. return to 1st menu
TYPE:     Q<CR>              .. quit program
```

The working directory now contains the *.DAI and the *.DDI data files.

DDFFLD - DDF Field Decomposition

The following sequence will generate the "applications" data files (*.APP) for the current data set(s).

```
TYPE:     DDFFLD<CR>         .. starts the program
TYPE:     <CR>               .. skip to 2nd menu
TYPE:     XXXXX/2            .. process this file
TYPE:     YYYYY/2            .. continue
            .
            .
TYPE:     <CR>               .. return to 1st menu
TYPE:     Q<CR>              .. quit program
```

Note: The /2 switch on the command line causes the output file format to be ASCII which makes editing, if required, easier.

The program performs data validation and an intermediate file format conversion.

The working directory now contains the *.APP data files.

MAKPN1 Data Conversion Package Ver 1.1

MAKPN1 - Make SENC Database

The following sequence will generate two scratch files (*.PTR and *.SGT) files which are useful if you only want to remake part of a SENC database cell, and two SENC database files (*.EDB and *.FTR) which contain the vector and feature data for display.

Note: The "responses" below are informative messages from the program and do not require action by the user.

```
TYPE:      MAKPN1<CR>          .. start the program
RESPONSE:  COMPILING LIST OF INPUT DATA ...
PROMPT:    Enter filename, e.g., D3600000
TYPE:      XXXXX<CR>

RESPONSE:  Note: You should update .PTR and .SGT
           files if you have run DDFFLD on this set
           since the last update.
PROMPT:    Create new .PTR and .SGT for this file
           (Y/N)?
TYPE:      Y
PROMPT:    Enter another file (Y/N)?  .. continue
                                         until all
                                         required
                                         files are
                                         selected,
                                         then
TYPE:      N<CR>
```

When the last file name has been entered, the processing commences.

Note: The .PTR and .SGT files do not have to be recreated unless changes have been made to a particular .DAI, .DDI, or .DDF file and DDFIMP and/or DDFDLD have been run again.

A single file or multiple files can be processed in a single run. All files selected during the running of the program will be included in the SENC database.

When MAKPN1 has finished, the working directory will contain *.PTR, *.SGT, *.EDB, and *.FTR data files. The *.EDB and *.FTR files will be discussed in the next section.

SENC Display Version 1.1

General Instructions

1. Change Directory (CD\) to directory containing vector database files (.EDB and .FTR) and display program (ECDIS.BAT and ECD_MAIN).

Example Directory

ECDIS	BAT	20	12-03-91	9:32a
EGAVGA	BGI	5363	08-29-88	2:00a
DOG	CHR	5259	07-18-91	2:29p
ECD	CHR	5145	07-17-91	11:06a
ECD2FNT	CHR	2322	07-18-91	3:23p
LITT	CHR	2524	07-18-91	3:28p
LITT_ECD	CHR	2524	07-18-91	3:28p
TEST	CHR	2609	07-22-91	4:43p
TRIP	CHR	16643	07-18-91	4:27p
D3600000	EDB	43420	12-03-91	9:31a
I6040853	EDB	200720	10-14-91	3:48p
I6040854	EDB	251628	10-14-91	4:10p
ECD_MAIN	EXE	230406	12-19-91	1:35p
D3600000	FTR	950	12-03-91	9:31a
I6040853	FTR	571	10-15-91	12:15p
I6040854	FTR	776	10-15-91	12:17p
ECD	HLP	4739	10-18-91	9:43a
FIND	TMP	118	01-23-92	10:39a

2. Type "ECDIS". Program will start and initial screen will be displayed.

3. Click on New File or press F7 to load vector database. Choose vector database for display by clicking on name in menu box.

4. Click on Draw Map or press F2 to display selected database.

5. At this point, any of the other program functions may be invoked (see below).

6. To terminate the program, click on Exit or press F10.

Command Summary

F1	Help	- Browse through Online Help.
F2	Draw Map	- Plot a selected ECDIS vector file.
F3	Track	- Show lat/long position of cursor.
F4	Find Feat	- Locate the file location (line number) of a feature, point or object on the map.
F5	Zoom	- Zoom at cursor location.
F6	Not Used	
F7	New File	- Select a new vector file to display.
F8	Read File	- Browse through the selected vector file.
F9	Change Feat	- Change the current display status (show/no show) of features in a vector file.
F10	Exit	- Leave the program.

Detailed Instructions

F1 Help -

Press the function key F1, or click the mouse on the F1 icon to view this file. See File Browser Instructions below for additional information regarding browse options.

F2 Draw Map -

Press the function key F2, or click the mouse on the F2 icon to instruct the program to plot a selected vector file. A file is specified either as a command line argument, or selected from within the program using option F7.

F3 Track -

Press the function key F3, or click the mouse on the F3 icon to view the cursor coordinates in longitude and latitude. The coordinates will be updated until a mouse button is pressed.

F4 Find Feat - (Find Feature)

Press the function key F4, or click the mouse on the F4 icon to select the Find Feature option. This option is used to locate the position within the vector file of a selected feature or point from a map on the display screen. To find a feature, enclose the feature to be searched within a box by clicking the Left Mouse Button to the left and above the feature, and then again to the right and below the feature. A box will be drawn as this is performed. After the box is drawn, the program will search through the vector file until either a match is found or until the end of file is reached. If no match is found, an error message will be presented, otherwise, a window will appear containing all lines within the vector file that contain points within the selected area.

F5 Zoom -

Press the function key F5 or click the mouse on the F5 icon to activate the zoom function. An area is zoomed by centering the cursor over the desired location and clicking the left mouse button. The map will remain zoomed until the mouse button is clicked again.

F6 Not Used

F7 New File -

Press the function key F7, or click the mouse on the F7 icon, to select a vector file (.EDB) to read. After selecting this option, a pop-up window will appear containing all available files. A file is selected by clicking the mouse on it, or by highlighting it using the arrow keys.

F8 Read File -

Press the function key F8, or click the mouse on the F8 icon, to activate the vector file browse option. This option will place a scrollable window on the screen containing the currently selected vector file.

F9 Change Feat - (Change Feature)

Press the function key F9, or click the mouse on the F9 icon, to select the Change Feature option.

This option allows individual as well as all features to be toggled on or off. If a feature is "off" it will not be displayed during map drawing. This is a convenient way to suppress features that clutter a display (depth readings, for example). To change the default display status of a feature, refer to the Feature File discussion below. To toggle all features either on or off, select the Change Feat option. After the feature box has been drawn, click the mouse anywhere outside the box without making any changes. An option box will then appear with three choices: (1) No changes, (2) Toggle all features off, and (3) Toggle all features on. Select the desired option by either clicking on it, or by highlighting it with the arrow keys.

F10 Exit

Press the function key F10 or click the mouse on the F10 icon to leave the program.

REFERENCES

[1] - Glossary of ECDIS-Related Terms, Rev 1.1, ECDIS Glossary Working Group, International Hydrographic Organization.

[2] - IHO Data Transfer Standard (DX90) Part B, Committee on Exchange of Digital Data, Feature Code Working Group, International Hydrographic Organization.

[3] - ECDIS Object Catalog: Release 1.0, Shiphandling and Simulation Facility, Deutsches Hydrographisches Institut (DHI).

[4] - ANSI/ISO 8211 Data Description File System, Alfred A. Brooks.

[5] - Provisional Performance Standards for Electronic Chart Information Systems (ECDIS), International Maritime Organization Sub-Committee on Safety of Navigation, 35th Session.

[6] - Provisional Specifications for Chart Content and Display of ECDIS, Special Publication No. 52, COE Working Group, International Hydrographic Organization.

[7] - Report on the IHO (COE) Working Group on Updating the Electronic Chart, Special Publication No. 52, Appendix 1, International Hydrographic Organization.

[8] - Provisional Presentation Standards for ECDIS, Special Publication No. 52, Appendix 2, IHO (COE) Working Group on Colours and Symbols, International Hydrographic Organization.

[9] - International Hydrographic Organization Transfer Standard for Digital Hydrographic Data, Special Publication No. 57, International Hydrographic Bureau, 1991.

[10] - RTCM Recommended Standards for Electronic Chart Display and Information Systems, Fifth Draft Report of RTCM Special Committee No. 109, Radio Technical Commission for Maritime Services.

BIBLIOGRAPHY

Manual of Remote, Sensing Second Edition, American Society of Photogrammetry, 1983

Management and Dissemination of Electronic Navigational Chart Data in the 1990s, Stephen Grant, Horst Hecht, Michael Casey, and Timothy Evangelatos.

1.0 Executive Summary

The Environmental Research Institute of Michigan (ERIM) was contracted by the United States Coast Guard Research and Development Center through the Naval Coastal Systems Center to prepare a set of technical and functional specifications that detail the means/processes required to perform the conversion of an Electronic Navigational Chart (ENC) in the DX90 Data Transfer Standard format into a System Electronic Navigational Chart (SENC). This report details the activities associated with transforming the DX90 data structures to an intermediary ENC format, developing the software to transform this intermediary ENC to a form which could be displayed (SENC), and developing display software to allow an operator to interact with the data. Based on these activities, insights were gained into the current status of the implementation of the DX90 standard as well as the strengths and limitations of this format to support Electronic Chart Display and Information System (ECDIS) applications. Outputs from this contract include this report and software to perform the data conversion and display functions on an IBM-compatible personal computer.

The major lessons learned during the project include the following:

Status of DX90 Implementation

Capability of DX90 to Support ECDIS

Capability of DX90 to Support GIS

Follow-on recommendations for RDT&E Activities include:

Generic DX90 SENC Display

Interactive Editing of Translated ENC Databases

Prototype GIS Database Structure

ABBREVIATIONS/ACRONYMS [1]

ANCSII	- Automated Navigational Chart System
DDFS	- Data Description File System
ECDB	- Electronic Chart Database. The master database for Electronic Navigational Chart Data (ENCD) held in digital form by the national hydrographic authority containing chart information and other nautical and hydrographic information.
ECDIS	- Electronic Chart Display and Information System. The navigation information system which is considered equivalent to the nautical paper chart, displaying selected information from the chart data base integrated with data from positional, and optionally other sensors.
ENC	- Electronic Navigational Chart. The data base, standardized as to content, structure, and format issued for use with ECDIS. This is the DX90 chart data provided by NOAA/NOS (USA HO).
GIS	- Geographic Information Systems
HO	- Hydrographic Office.
IHO	- International Hydrographic Organization
NOAA/NOS	- National Oceanographic and Atmospheric Administration/National Ocean Service
SENC	- System Electronic Navigational Chart. This is the format the vendor produces for describing chart data. This format is in a readable and indexed form, ready to be manipulated by the vendor to suit individual user needs, such as displaying the chart.